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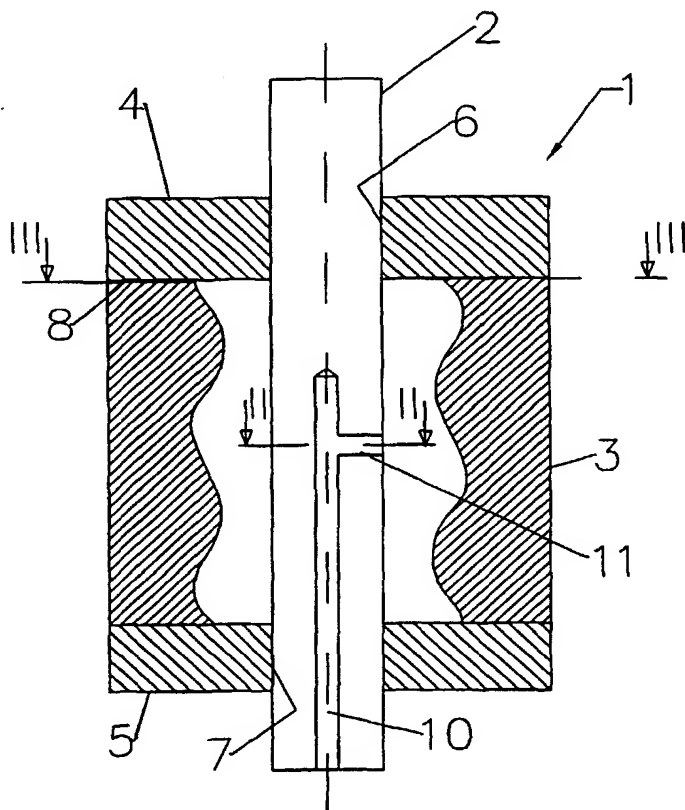
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(54) Title: METHOD FOR PRODUCING POLYMER ROTORS



(57) Abstract: The invention relates to a method of manufacturing a rotor (12) for a helical screw machine that includes a metal shaft (2) and helical lobes (9) mutually separated by intermediate grooves (13), comprising the steps of providing the shaft (2) with a blind axially extending passageway (10); connecting the passageway (10) with the barrel surface of the shaft (2) by means of at least one channel (11) extending outwardly from the shaft; inserting the rotor shaft (2) in a mould (1) that includes two mutually spaced end-walls (4, 5) which have respective rotor shaft receiving openings (6 and 7), said openings (4, 5) embracing the rotor shaft (2, 19) at least in a generally sealing fashion; heating the mould (1) and the shaft (2) to the curing temperature of the polymer; delivering polymer-forming materials to the mould (1); maintaining the barrel wall (3) of the mould (1) at said curing temperature until the polymer has cured; and removing the rotor from the mould (1). The method is characterised by the further steps of disposing the outwardly extending channel (11) on the shaft (2) such that said channel will be located generally in the middle of the mould (1) when the shaft (2) is inserted therein; and pressing the polymer into the axially extending passageway (10) at an overpressure of at least 1 bar.

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METHOD FOR PRODUCING POLYMER ROTORS

The present invention relates to a method of manufacturing a polymeric rotor that includes a metal shaft having anchored thereon a polymeric body with helical lobes
5 mutually separated by intermediate grooves, for a helical screw machine, such as a helical screw compressor and helical screw expander.

Rotors for helical screw machines include a metal shaft that has a rotor body affixed thereto. This rotor body has helical lobes mutually separated by grooves. Metal rotors are conventionally produced in one piece, whereas polymeric rotors have a metal
10 shaft to which there is affixed a polymeric rotor body. The rotor body has at least two lobes, normally 4-7 lobes. A helical rotor machine will normally includes two mutually co-acting rotors, of which one rotor is a male rotor with typically relatively strong lobes, and the other rotor is a female rotor which normally has relatively weaker lobes. The rotor body surrounding the metal shaft is a coherent body in which the grooves
15 separating the lobes have only a small material thickness, particularly in respect of a female rotor.

DE-A1-39 03 067 teaches the manufacture of a rotor for helical screw machines. According to this publication, a metal shaft is placed vertically in an open top matrix, whereafter a liquid polymer is either delivered to the outside of the shaft or through a
20 passageway in the centre of the shaft, wherein channels extend radially to the shaft periphery from the lower end of the passageway. These channels open into the matrix at the lower end of the cavity to be filled with the liquid polymeric material. It is stated in the publication that this latter alternative is to be preferred when casting female rotors, that is to say female rotor bodies, of small thickness in the grooves between the lobes of
25 the rotor. These radially extending channels open into the lower part of the cavity that has the smallest outer diameter.

When the polymer is delivered through the central passageway in the metal shaft in accordance with this publication, it is necessary that the polymer remains liquid in the lower part of the mould throughout the time taken to fill the mould completely. It is not
30 until this has been achieved that conditions can be applied which cause the polymer to transform to a solid state in the lower part of the mould.

It has been found that rotors produced in this way have a smaller diameter in the centre of the rotor than at the ends thereof. The contraction or shrinkage that results in this hourglass shape may be due to the solidification of the polymer at a lower

temperature at the ends of the rotor than at its centre. The higher temperature in the centre of the rotor results in more pronounced shrinkage.

An object is to provide a method of manufacture that eliminates the drawbacks associated with the known method and therewith obtain rotors that do not have a waisted
5 centre part in an axial direction.

In accordance with the present invention, a polymeric rotor for a helical screw machine that includes a metal shaft and at least two helical lobes mutually separated by intermediate grooves is manufactured by providing the shaft with an axially extending blind passageway, connecting the axially extending passageway with the barrel surface
10 of the shaft by means of at least one radially extending channel, inserting the metal shaft in a mould comprising two mutually spaced end walls that include mutually opposed central openings that receive the rotor shaft, said openings sealingly enclosing the metal shaft at least generally, heating the mould and the metal shaft to the polymer curing temperature, delivering polymer-forming materials to the mould, maintaining the mould
15 and the metal shaft at said curing temperature until the polymer has been cured, and then removing the metal shaft with rotor from the mould. The inventive method is characterised in that the radial channel extending outwards from the passageway is arranged in a manner such that said channel will be situated generally in the middle of the mould when the shaft is inserted therein, and in that the polymer is pressed into the
20 axially extending passageway at an overpressure of at least 1 bar.

Preferred embodiments of the method will be apparent from the dependent Claims. The polymer material, release agent, and filler may be those described in the German reference or other materials known to the person skilled in this art.

According to one preferred embodiment of the invention, the metal shaft includes
25 helical recesses or grooves that are filled with polymeric material and that form a sunken part of the outwardly lying lobe. The recesses or grooves will preferably have a parallel trapezium cross-section, with the shorter of the parallel sides located nearest the shaft periphery and extending perpendicularly to the shaft radius. The corners at the transition from the non-parallel sides to the shaft periphery are rounded, to reduce the fracture
30 tendency of the polymeric material.

The helical grooves may extend along the full length of the lobe or solely along a part thereof. Similarly, the helical grooves may be two or more along part-grooves disposed along the same helical line. In this latter case, it is preferred that an outwardly directed channel opens into each part-groove.

According to the invention, the term metal alloys includes, for instance, steel and brass, wherewith steel is particularly preferred. The polymeric material may be polyurethane containing inorganic filler, for instance silicate-containing fibres.

The invention will now be described by way of example and with reference to the
5 accompanying drawing, in which

Figure 1 is a schematic longitudinal section view of a mould according to the invention and shows a metal shaft inserted in the mould;

Figure 2 is a sectional view of the metal shaft, taken on the line II-II in Figure 1;

Figure 3 is a sectional view of a first form of a known rotor end profile, taken on
10 the line III-III in Figure 1;

Figure 4 is a sectional view of a second embodiment of a rotor end profile, taken on the line III-III in Figure 1; and

Figure 5 is a schematic vertical sectional view of a static mixer.

Figure 1 shows a mould 1 in which a metal shaft, preferably a steel shaft 2, is
15 inserted. The barrel wall 3 of the mould 1 has a cylindrical outer surface and internally the outer contour of a helical rotor, which in the illustrated case includes five lobes and an equal number of intermediate grooves, as shown in Figure 3. The mould 1 includes an upper circular end-wall 4 and a lower circular end-wall 5. Each of the end-walls 4, 5 is provided with a respective central, shaft-receiving opening 6 and 7. The openings 6, 7
20 embrace the rotor shaft 2, such as to at least generally seal against said shaft. The mould 1 includes in the upper part of the barrel wall 3 an air vent 8 for each rotor lobe 9, as will be seen from Figure 3. These air vents 8 may also be disposed as grooves in the upper end-wall 4.

The rotor shaft 2 has at its lower end a central, axially extending passageway 10
25 that extends more than half way into the shaft 2. As will be seen from Figure 1, those end-parts of the shaft 2 that are located outside the end-walls 4, 5 are of equal lengths. If the shaft 2 is placed asymmetrically in the mould 1, the length of the axial passageway 10 will extend beyond the centre of the mould 1 surrounding the shaft.

At least one radial channel 11 extends to the periphery of the shaft 2 from the
30 passageway 10. The number of radial channels 11 extending from the axial passageway 10 to the periphery of the shaft will preferably equal the number of lobes 9 to be provided on the rotor. These radial channels 11 are preferably offset relative to each other in the axial direction of the shaft, so as to reduce or minimise weakening of the shaft in the region of said channels 11.

Figure 2 shows the shaft 2 and one such radial channel 11 and two further channels 11' and 11'' shown in broken lines, these further channels being located beneath the surface of the section. Although not shown, the shaft includes a further two radial channels 11 above the section surface.

5 Figure 3 illustrates an end section of a male rotor 12 that has five lobes 9. These lobes 9 are mutually separated by grooves 13. It will be apparent from this Figure that the mould has five air vents 8 in its upper part.

Figure 4 is an end section of a female rotor 14 that has six lobes 15 and six intermediate grooves 16, said rotor being inserted in a mould 17. The rotor is formed in
10 accordance with the invention. The rotor body 14 is disposed on a steel shaft 19 and has the form of six individual and mutually separated lobes 15. It will be seen from the Figure that the bottoms of respective grooves 16 between the lobes 15 are formed by the steel shaft 19. The lobes 15 are thus not mutually connected by polymeric material as in the case of the lobes 9 of the male rotor shown in Figure 3. The mould includes six air
15 vents 18. The rotors produced in accordance with Figures 3 and 4 are not intended to interact with each other.

As will be seen from Figure 4, the shaft 19 includes recesses 20 that are trapezoidal in cross-section, wherewith the longer of the mutually parallel surfaces face towards the centre point of the shaft 19. The non-parallel surfaces have rounded corners
20 at the shaft periphery. These trapezoidal recesses 20 widen in the same helical shape as the outwardly lying lobe 15. In one preferred embodiment of the invention, each radial channel 11 (Figure 2) opens into one such recess 20. The recesses 20 widen from the radial channel 11 over a longer or shorter distance. In the case of the embodiment shown in Figure 4, the recess 20 has the same length as the lobe 15. These recesses 20 are
25 effective in the affixment of the polymer in the shaft 19. The rounded corners at the periphery of the shaft 19 reduce the risk of crack formation and lengthen the useful life of the rotor.

Figure 5 is a schematic vertical sectional view of a static mixer 30 for use in moulding inventive polymeric rotors. The mixer 30 includes a first conduit 31 that has
30 two inlet openings 33, 34 at respective ends thereof. A third opening 35 that connects with one end of a second conduit 32 is provided in the conduit wall between said openings 33, 34. This second conduit includes a number of mixing elements 36, which may be helically shaped. The elements 36 are arranged to prevent material passing

axially through the second conduit 32 without mixing. Such static mixers are known to the art.

According to the invention, a liquid or solid polymeric material, e.g. polyurethane, preferably containing filler, is delivered to the axially extending, central passageway 10 at a temperature of about 30°C and at an overpressure of at least about 1 bar and at most about 15 bar. The preferred pressure lies about midway of this pressure range. The mould 1 and the shaft 2 have been heated to a temperature of about 90°C. A release agent may have been applied to the inner surface of the mould 1 prior to delivering the polymeric material. The barrel 3 of the mould is also heated electrically so as to maintain a temperature of about 90°C, this being done conventionally. The shaft 2 and the end-walls 4, 5 of the mould have a high thermal capacity and are therefore not heated. The polymeric material delivered to the axially extending passageway 10 leaves said passageway through the radially disposed channels 11.

The material exiting from the radial channels 11 first flows down in the upstanding mould 1 and thereafter rises in the mould cavity until the mould has been filled. Because the material delivered has a much lower temperature than the shaft 2 and the mould 1, the material will take up heat as it is delivered, while cooling the shaft 2 and the non-heated end surfaces. Because the material is delivered centrally in the mould 1, the material will be located where the lowest temperature prevails at the beginning of the solidification process. The fact that the material is delivered under a relatively high overpressure in precisely the centre of the mould 1, shrinkage of the polymer, normally occurring in the centre, is compensated for so that the rotor will not have a smaller diameter in the midway zone of the rotor than the diameter of the ends of the rotor.

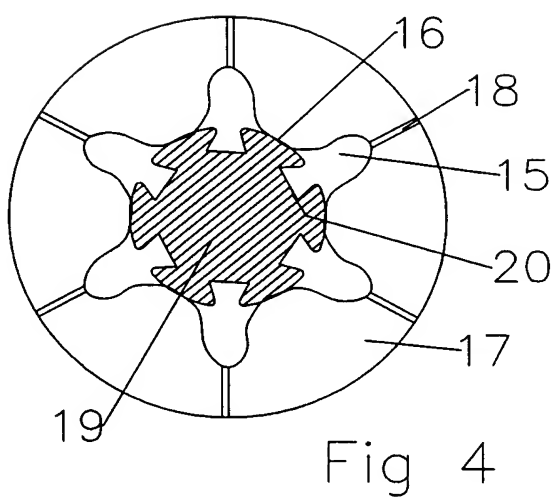
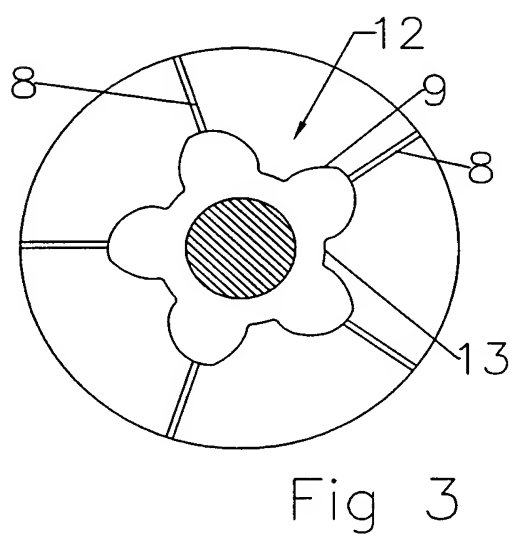
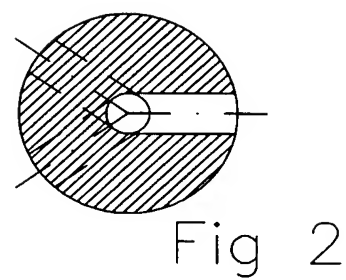
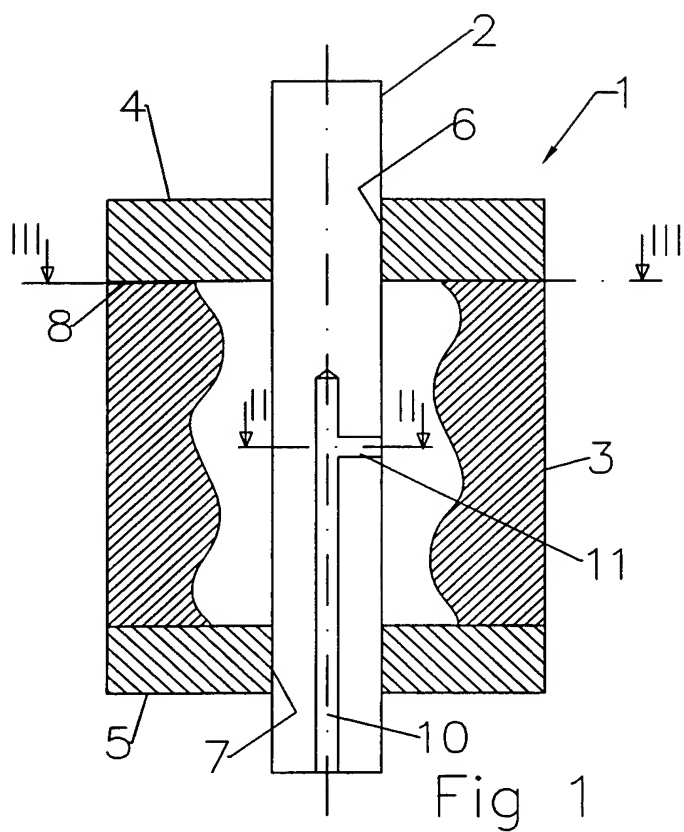
According to a second embodiment of the invention, a static mixer 30 is placed in the central passageway 10. The length of the second conduit 32 of the static mixer is such that when the mixer is inserted it will only reach as far as the radially extending channels that lie nearest the orifice of the central passageway. This enables two components that together form the polymer after being cured to be delivered through a respective opening 33, 34 of the static mixer 30, said components passing through the opening 35 and into the second conduit 32 of the mixer. The components are mixed in the second conduit with the aid of the mixing elements 36, which induce lateral movement of the material.

CLAIMS

1. A method of manufacturing a rotor (12, 14) for a helical screw machine that includes a metal shaft (2, 19) and helical lobes (9, 15) mutually separated by intermediate grooves (13, 16), comprising the steps of
- 5 - providing the shaft (2, 19) with a blind axially extending passageway (10);
- connecting the passageway (10) with the barrel surface of the shaft (2, 19) by means of at least one channel (11);
- inserting the rotor shaft (2, 19) in a mould (1) that includes two mutually spaced end-
- 10 walls (4, 5) that include respective rotor shaft receiving openings (6 and 7), said openings (4, 5) embracing the rotor shaft (2, 19) at least in a generally sealing fashion;
- heating the mould (1) and the shaft (2, 19) to the curing temperature of the polymer;
- delivering polymer-forming materials to the mould (1);
- 15 - maintaining the barrel wall (3) of the mould (1) at said curing temperature until the polymer has cured; and
- removing the rotor from the mould (1),
- characterised** by the further steps of disposing the outwardly extending channel (11) on the shaft (2, 19) such that said channels will be located generally in the middle of the
- 20 mould (1) when the shaft (2, 19) is inserted therein; and pressing the polymer into the axially extending passageway (10) at an overpressure of at least 1 bar.
2. A method according to Claim 1, **characterised** by providing the rotor shaft (2, 19) with a radially extending channel (11) for each lobe (9, 15), wherewith the channels (11)
- 25 are disposed symmetrically around the circumference of the shaft.
3. A method according to Claim 2, **characterised** in that the channels (11) are offset relative to each other in the axial direction of the rotor shaft (2, 19).
- 30 4. A method according to Claim 2 or 3, **characterised** by positioning the shaft (2, 19) in the mould (1) such that an outwardly directed channel (11) opens into each lobe (9, 15).

5. A method according to Claim 2 or 3, **characterised** by providing the rotor shaft (2, 19) with helical recesses (20) that have the same helical form as the lobes (9, 15) and that each intersect a respective channel (11).
- 5 6. A method according to Claim 4, **characterised** by mixing the material in the axially extending passageway (10).
7. A method according to Claim 1, **characterised** by placing a static mixer (30) in the central passageway (10) and feeding a polymer-forming component through the opening (33) of the mixer, and feeding a further polymer-forming component through
10 the other opening (34).

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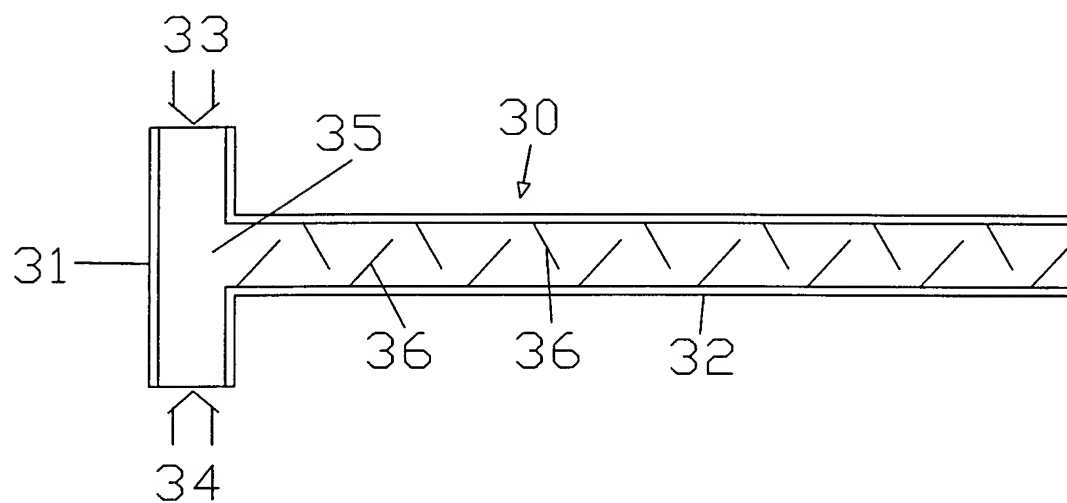


Fig 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/01998

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B29C 39/10, F04C 18/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B29C, F04C, B29D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, PAJ, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| A | DE 3903067 A1 (GVM GESELLSCHAFT FÜR SCHRAUBENVERDICHTER- UND SCHRAUBENMOTORENTECHNOLOGIE MBH), 9 August 1990 (09.08.90), figures 1,2, claims 1,2, abstract -- | 1-7 |
| A | WO 9304811 A1 (OPCON AUTOROTOR AB), 18 March 1993 (18.03.93), figures 1-5, claim 1, abstract -- | 1-7 |
| A | WO 8909881 A1 (SVENSKA ROTOR MASKINER AB), 19 October 1989 (19.10.89), figure 1, claim 1, abstract -- | 1-7 |

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|---|-----------------------|
| A | SE 503730 C2 (SVENSKA ROTOR MASKINER AB), 12 August 1996 (12.08.96), figure 1, claim 1, abstract -- ----- | 1-7 |

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE 00/01998

| Patent document cited in search report | | | Publication date | Patent family member(s) | Publication date |
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| DE | 3903067 | A1 | 09/08/90 | NONE | |
| WO | 9304811 | A1 | 18/03/93 | DE 69206624 D,T EP 0602143 A,B JP 6510353 T SE 502265 C SE 9102530 A | 25/07/96 22/06/94 17/11/94 25/09/95 04/03/93 |
| WO | 8909881 | A1 | 19/10/89 | DE 68907054 D,T EP 0411000 A,B JP 2833808 B JP 3503667 T SE 463040 B,C SE 8801276 A US 5219499 A | 18/11/93 06/02/91 09/12/98 15/08/91 01/10/90 08/10/89 15/06/93 |
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